ARKIV FÖR FYSIK Band 3 nr 28

Communicated 23 May 1951 by G. BORELIUS and LISE MEITNER

A neutron counter using proton recoils from a solid hydrogenous radiator

By YNGVE AXNER and BENGT SWENSON

With 6 figures in the text

Abstract

An ionization chamber with a solid hydrogenous radiator for neutron measurements is described. The theoretical calculation of the sensitivity is experimentally verified with D — D-neutrons. The spectrum of the recoil-protons is measured with a 10-channel pulse amplitude analyser.

Introduction

Neutron counters with hydrogenous radiators are used for the measurement of relative and absolute neutron fluxes and for the determination of neutron energy distributions. Several different types of counters are possible. We have chosen a grid chamber with electron collection and a solid radiator. Neutron energies must often be measured in the presence of γ-rays. Electron collection times are of the order of microseconds and thus the piling up of γ-pulses can be held at a low level. The advantage of a solid radiator is that the sensitivity can be accurately calculated, the chemical composition of the radiator and the range-energy relation for the protons in the radiator being known.

The ionization chamber

The ionization chamber has 3 electrodes: a radiator electrode, a grid, and a collecting electrode (Fig. 1). The grid shields (with good efficiency) the collecting electrode from the influence of the positive ions, and thus the output pulse from the chamber will be directly proportional to the ionization and will not depend on the position of the ionizing track.

The gas filling is cylinder argon vith 98.1 % Ar, 1.9 % N_2 and less than 0.0002 % O_2. The gas pressure has been up to 10 atm. No purification of the gas has been necessary.

Six different radiators can be put in the chamber at the same time. A simple magnetic coupling makes it possible to place the desired radiator in the measuring position. Thus measurements can be made with radiators of different

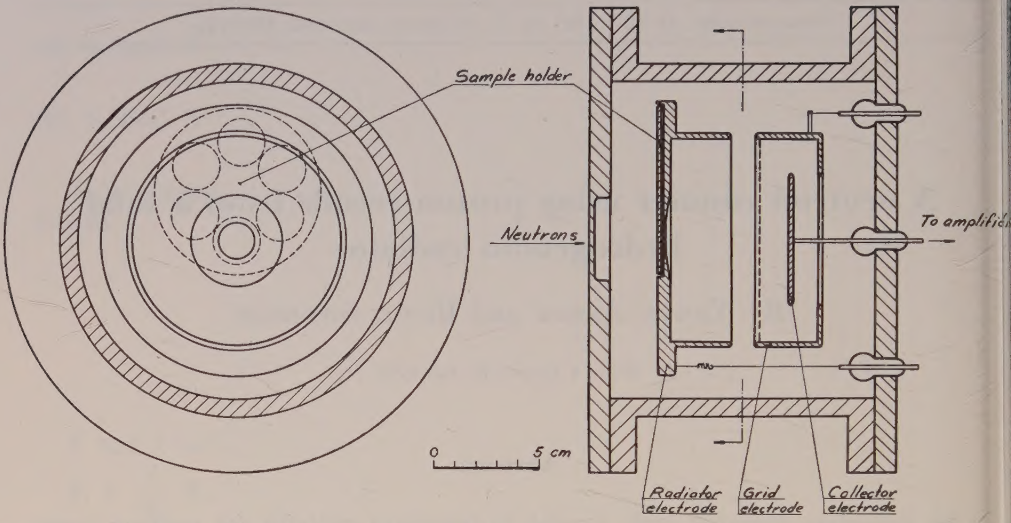

Fig. 1. The ionisation chamber.

thickness and with α-particles (in order to get the energy scale) without refilling the chamber.

The voltage of the electrodes has been about — 2 000 and — 1 000 volts.

The amplifiers and the pulse analyser

The amplifiers are of a rather conventional type with negative feedback, careful screening, good filtering of the heater currents in the first valves, and carefully stabilized power-supplies.

The pulse amplitude analyser has 10 channels, the bias voltage and the channel width being variable. The counting rate is limited by the mechanical registers to about 12 pulses per second. The analyser has been described elsewhere (1).

The van de Graaff generator

The experiments have been performed with D — D-neutrons from the 1 MeV-van de Graff generator at the Physics Department of the Royal Institute of Technology, Stockholm. The generator will be described elsewhere (2).

The experimental results

A block diagram of the experimental arrangement is given in Fig. 2. The monitoring ionization chamber is of the same type as the measuring chamber.

Experiments were first carried out with the ionization chamber and the electronic equipment in order to test the resolution of the system. Electrolytically deposited uranium was placed on the high voltage electrode and the

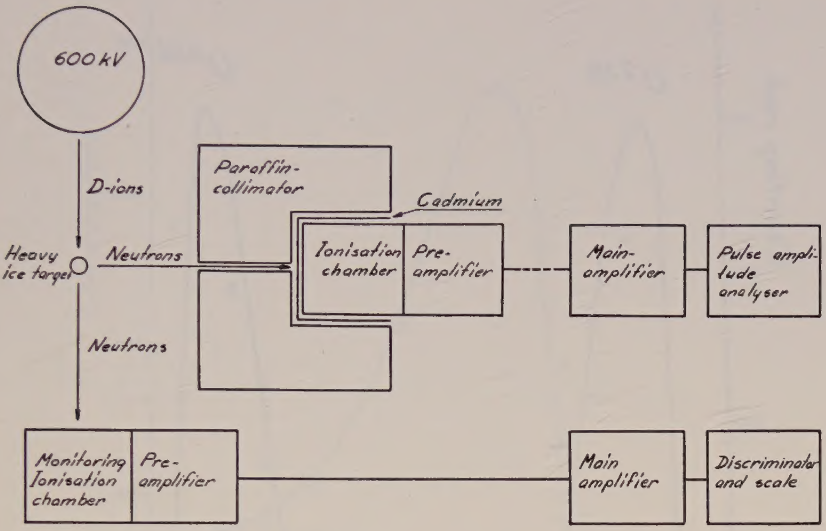

Fig. 2. Block diagram of the experimental arrangement.

chamber filled with 1–2 atm. argon. The result of 4 overlapping measurements is shown in Fig. 3. The resolution is sufficient to show a U 235-peak between the U 238 and U 234-peaks.

The radiators were first prepared from ordinary paraffin by distillation in vacuum. The results were not satisfactory. The reason may be that the composition of the radiators changed during the distillation. We then tried ordinary candle stearin, which was melted on metal plates. They are easy to prepare but have the disadvantage of not being of quite uniform thickness. Furthermore the exact chemical composition is unknown and the stearin reacts with the metal. But they give quite satisfactory results, so we never used the glycerol tristearate radiators, which were prepared later on and which will probably be the best ones.

When first using our chamber for neutron measurements, we had great difficulty in getting reproducible results. The reason was that the sensitivity often changed after a new gas filling. We therefore constructed a new radiator electrode, in which six different samples could be placed on the same eccentric circular disc. Some gears and a magnetic coupling made it possible to change radiator without refilling the chamber (see Fig. 1). With this modification it was possible to make comparative measurements.

The electrodes were gold-plated in order to diminish the zero-effect from hydrogen on the electrodes. The polystyrene insulators were surrounded by glass tubes for the same reason.

The chamber was surrounded by a 2 mm sheet of cadmium in order to absorb the slow neutrons. The fast neutrons were collimated through a hole, 40 cm long and 2.5 cm in diameter in a paraffin box surrounding the chamber.

The neutrons were produced by accelerating 600-keV-deuterons on to a thick

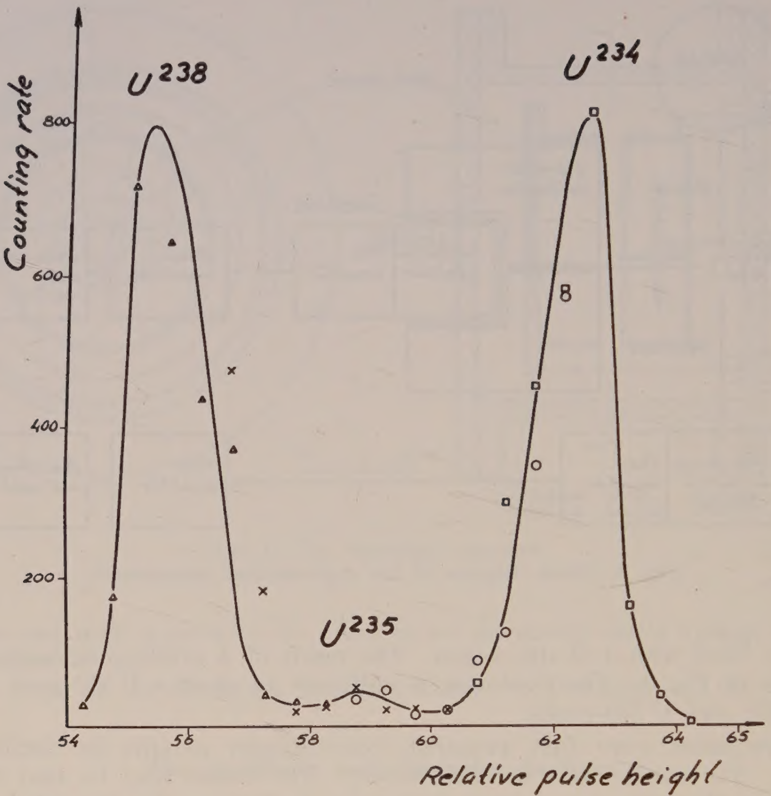

Fig. 3. Differential pulse-height distribution for α-particles of normal uranium.

heavy-ice target. The measurements were made at an angle of 90° to the deuteron-beam. The neutron energy in this direction is

$$E_n = \tfrac{3}{4}Q + \tfrac{1}{4}V$$

where $Q = 3.28$ MeV (3) and V = the accelerating voltage, which gives

$$E_n = 2.61 \text{ MeV}.$$

The neutrons in the 90° direction are almost mono-energetic and changes in the accelerating voltage do not have much influence on the measurements.

The energy scale of the measurements was determined by α-particles from polonium, which have an energy of 5.40 MeV (4).

Two different grids have been used, both consisting of parallel wires with the following data:

Wire diameter	0.12	0.15	mm
Spacing	2.5	1.0	mm
Screening fraction	4.8	15	%
Distance from collecting electrode	15	15	mm
Amplification factor	20	120	

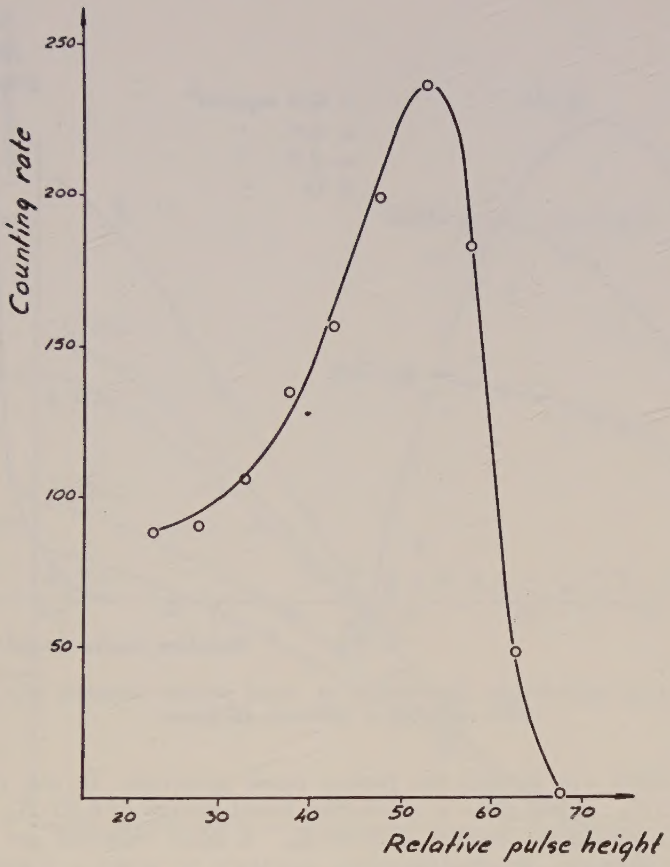

Fig. 4. Differential pulse-height distribution of recoil protons obtained with the chamber, when the pressure was low. The thickness of the radiator is 2.5 mg/cm^2.

The screening fraction and the amplification factor are quantities used for triodes, and formulas for them are found in radio handbooks (5). The amplification factor is a measure of the ability of the grid to screen the collecting electrode from the positive ions.

The experiments show that the screening action of both grids is sufficient, if the pressure in the chamber is so high, that no ionization occurs within a distance of about 5 mm from the grid. If the pressure is not high enough, that is to say, if the ends of the proton tracks with their high ionization lie in the vicinity of the grid, the screening action will to some extent disappear. The spectrum of the pulses will then tend to the spectrum that would be obtained without grid. A theoretical calculation shows that in this case (plane electrodes, no grid, electron collection) the spectrum has a peak at the high energy end. That is exactly what we found with low pressure in the chamber (see Fig. 4).

If on the contrary we use a high pressure, we will get a larger number of

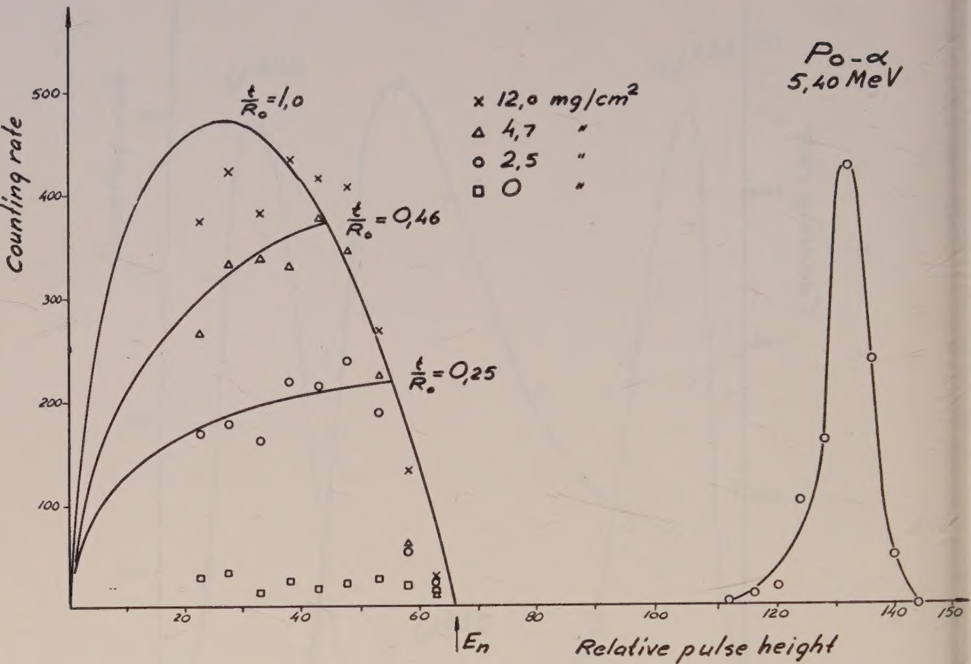

Fig. 5. Differential pulse-height distribution of recoil protons obtained with the chamber with radiators of different thickness.

gas recoils, which will disturb the proton recoil spectrum. In our chamber gas we had 1.9 % N_2, which gives a maximum recoil energy of $0.25 \cdot E_n$. The argon pulses have a maximum energy of $0.095\ E_n$. A good chamber gas should not contain any nitrogen. It was therefore necessary to make a compromise and use a pressure that is neither too low nor too high. We have made our neutron measurements at a pressure of 5.3 atm.

The results of our measurements are given in Figs. 5 and 6. The theoretical curves are those calculated in (6). The theoretical energy limit is indicated by an arrow. At lower energies the experimental curves lie higher than the calculated ones on account of the gas recoils. The bias energy has been so chosen that we do not register any gas recoils. The four curves are all obtained after 50 000 pulses in the monitor chamber.

The thickness of the radiators has been obtained by weighing. The range of the 2.61 MeV-protons in the stearine has been assumed to be 10.2 mg/cm², which is the figure calculated by HIRSCHFELDER and MAGEE (7) for protons in glycerol-tristearate $C_{57}H_{110}O_6$. The range of the protons in argon at NTP is 11.4 cm (7).

The weights of the four radiators are 12.0, 4.7, 2.5, and 0 mg/cm², which gives a relative thickness $\left(\frac{t}{R_0}\right)$ of 1.00 (1.18), 0.46, 0.25, and 0.

The agreement between the experimental and theoretical curves is as close as one could expect for the differential curves. But in the integral diagram

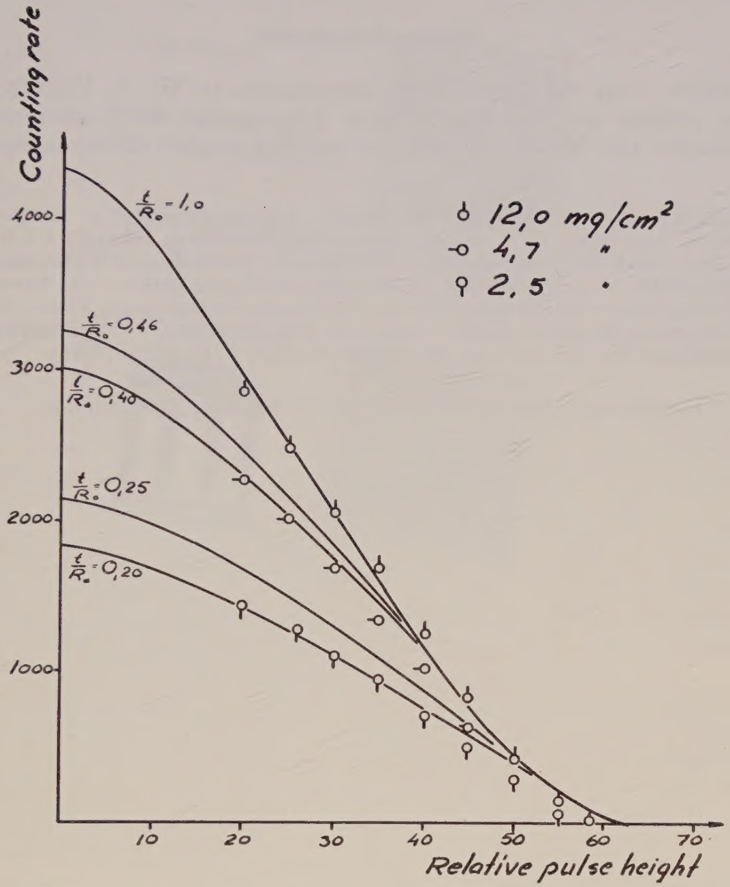

Fig. 6. Integral pulse-height distribution of recoil protons obtained with the chamber with radiators of different thickness.

two of the radiators give values which lie lower than the theoretical curves The error, which is about 8 % for $\frac{t}{R_0} = 0.46$ and 15 % for $\frac{t}{R_0} = 0.25$, may lie in the weighing, which is accurate to about 0.3 mg/cm^2 and in the calculation of the range of the protons in the radiator. The form of the experimental integral curves are in good agreement with the theoretical ones $\left(\text{compare } \frac{t}{R_0} = 0.40 \text{ and } 0.20\right)$.

The differential curves are of course a more rigorous test than the integral ones.

Acknowledgements

The authors wish to express their appreciation to Dr. S. EKLUND for proposing the subject and for very valuable help during the experiments and to Mr. P. HOLMÉN and Mr. G. ÖHMAN for assisting in the measurements.

REFERENCES. (1) **von Dardel,** Preliminary Announcement of a Differential Pulse Analyzer. Arkiv för fysik, bd 1 nr 26 p. 548. — (2) **Forsberg, Isberg,** A 1 MeV van de Graaff Generator. Arkiv för fysik, in press.— (3) **Hanson, Taschek,** and **Williams,** Rev. Mod. Phys. 21, 635 (1949). — (4) **Mattauch,** Nuclear Physics Tables 1946). — (5) **Terman,** Radio Engineer's Handbook. — (6) **Axner,** Theory of a Neutron Counter using Proton Recoils from a Solid Hydrogenous Radiator. Arkiv f. fysik, bd 3 nr 27 p. 491. — (7) **Hirschfelder,** and **Magee,** Declassified Documents from Manhattan Project, P. B. 52728 (1946).

Physics Department, Royal Institute of Technology, Stockholm.

Tryckt den 25 oktober 1951

Uppsala 1951. Almqvist & Wiksells Boktryckeri AB